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Sex determination from the talus in a contemporary Greek population using discriminant function analysis

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ABSTRACT

The determination of sex is an important part of building the biological profile for unknown human remains. Many of the bones traditionally used for the determination of sex are often found fragmented or incomplete in forensic and archaeological cases. The goal of the present research was to derive discriminant function equations from the talus, a preservationally favoured bone, for sexing skeletons from a contemporary Greek population. Nine parameters were measured on 182 individuals (96 males and 86 females) from the University of Athens Human Skeletal Reference Collection. The individuals ranged in age from 20 to 99 years old. The statistical analyses showed that all measured parameters were sexually dimorphic. Discriminant function score equations were generated for use in sex determination. The average accuracy of sex classification ranged from 65.2% to 93.4% for the univariate analysis, 90%–96.5% for the direct method and 86.7% for the stepwise method. Comparisons to other populations were made. Overall, the cross-validated accuracies ranged from 65.5% to 83.2% and males were most often correctly identified. The talus was shown to be useful for sex determination in the modern Greek population.

1. Introduction

When identifying human remains, the determination of sex is of primary significance as the determination of stature and age at death is sex dependent. Sex from skeletal remains may be determined through morphologic (non-metric) or metric analyses. The non-metric method is subjective as it uses observation of morphology and its accuracy is dependent on the experience of the observer.[1] The metric method is objective in that it employs measurements and statistical results that can be repeated and validated.[2] Metric methods can also detect dimorphism in skeletal traits that may be characterized as ambiguous by morphological assessments.[3,4] The Daubert and Mohan criteria emphasize the need for objectivity and standardized methodologies in the forensic sciences. These developments have changed "the standards by which [forensic anthropologists] determine what should count as an admissible problem, or as a legitimate problem-solution".[5]

The pelvis and skull have been shown to be the most accurate bones for the determination of sex.[6–9] However, incomplete or fragmentary bones are frequently excavated at forensic and archaeological sites due to postmortem damage and taphonomic changes. Current research has applied metric methods to postcranial elements and shown high accuracy rates for the determination of sex.[10–12] Therefore, developing methods for estimating sex from preservationally favoured and/or fragmentary bones is essential. Researchers have reported high accuracy rates for sex estimation from fragmentary skeletal remains, however the accuracy of using the talus for sex estimation in a modern Greek population has not been investigated to date.[13–31]

The talus has been shown to be useful for human identification as it is often well preserved during excavations and easily distinguished even in a fragmentary state due to its unique morphology.[4] This increased preservation is related to the increased strength and density of the bone's trabeculae and because it is often encased in socks and/or shoes.[32] Although research has shown high accuracy

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rates for sex determination from the talus these studies have cited the methods to be population specific.[13–31]

Due to seasonal fluctuations in the soil conditions in Greece, human skeletons are often fragmented or incomplete which results in limited availability of skeletal elements for analysis.[33] The goal of the present research is to derive discriminant function equations from the talus for sexing skeletons from a contemporary Greek population. Discriminant function analysis is appropriate for this project because it is primarily used to classify individuals into two (males and females) or more uniquely defined populations.

2. Materials and methods

This research utilized 182 individuals (96 males and 86 females) from the University of Athens Human Skeletal Reference Collection; the Collection consists of 225 documented skeletons. The individuals ranged in age from 20 to 99 years old. The Collection comprises individuals acquired from cemeteries from the surrounding area. Since the 1990's, skeletal remains have been donated to the University of Athens through a legal agreement with the municipalities; the skeletal remains of deceased individuals whose family members are unable to pay "rent" for their tomb are donated to the University of Athens. Complete demographics about each individual are known as death certificates provide information on sex, age, cause of death, occupation, and place of birth. The Collection represents individuals who have lived within the last half of the twentieth century. This skeletal collection was chosen for the current research project because it represents a contemporary Greek population.

Two sample sets within the age range of 20–99 years old were randomly selected for this research. Sample 1 (original group) consisted of 81 male and 71 female tali. This sample was used in the derivation of discriminant function equations for sex determination. Sample 2 (cross-validated group) consisted of 15 male and 15 female tali (N = 30). The skeletal elements used for Sample 2 were an independent sample; none of the bones used for Sample 2 were measured for Sample 1. Sample 2 was used to test the accuracy of the discriminant function equations that were derived using Sample 1.

Nine measurements were collected from each talus as described by Bidmos and Asala (2003) and Steele (1976). The measurements used were the talar length (TL), head-neck length (HNL), trochlear length (TrL), length of posterior articular surface (LPAS), talar width (TW), trochlear breadth (TrB), breadth of posterior articular facet (BPAS), head height (HH), talar height (TH). Fig. 1 shows these measurements. All metric values were collected by one observer with a digital vernier caliper and measured to the nearest 0.0 l mm. A comparison of the measurements taken from paired tali showed no statistically significant side differences with $p > 0.005$ (Bonferroni adjustment). Therefore, only the left talus was measured. The right talus was used if the left bone was missing or showed signs of pathology or trauma. Tali that displayed changes due to pathology or trauma were not included. Intra- and inter-observer rates were calculated by re-measuring 30 randomly selected tali (15 males and 15 females) from Sample 1 for each measurement variable. There were two observers. The measurements between observers were collected one week apart.

All statistical analyses were performed with the SPSS (version 21.0) software program, with a Bonferonni-adjusted level of significance $\alpha = 0.005$. Descriptive statistics were obtained for each measurement. Males and females were analyzed separately. Using a two sample *t*-test the mean values of the nine measurements were compared between the sexes to determine if statistically significant differences existed. The measurements were also classified into three categories for analysis: length measurements (TL, HNL, TrL, LPAS), breadth measurements (TW, TrB, BPAS), and height measurements (HH, TH). Demarcation points were calculated from the univariate analysis as a way of determining sex from individual measurements. These points are the average of the means of both sexes for each variable. The ungrouped and grouped variables were subjected to direct and stepwise discriminant function analyses. The Greek tali measurements were compared with other populations using two sample *t*-tests: white South Africans, black South Africans, and Koreans. A paired *t*-test was used to calculate the intra- and inter-observer error rates for each measurement variable.

All data were tested for normality and all variables were normally distributed with a Bonferonni-adjusted level of significance $\alpha = 0.005$; males and females were tested separately and all ages combined. As the variables were not skewed, means and standard deviations were used as the most appropriate measures of central tendency. The two sample *t*-tests were selected as the appropriate statistical test because the sample was randomly and independently selected, the variances were similar for the measurements, and the data exhibited a normal distribution.

3. Results

3.1. Inter- and intra-observer error rates

Using the Bonferonni-adjusted level of significance ($\alpha = 0.005$) none of the tests were statistically significant for any of the variables therefore there were no differences between or within observers. Statistically acceptable coefficients of reproducibility could be obtained.

3.2. Assessment of sexual dimorphism

Table 1 shows the results for the assessment of sexual dimorphism. All p-values are less than 0.005 (with a Bonferonni-adjusted level of significance $\alpha = 0.005$) indicating the presence of significant sexual dimorphism in all measured variables of the talus.

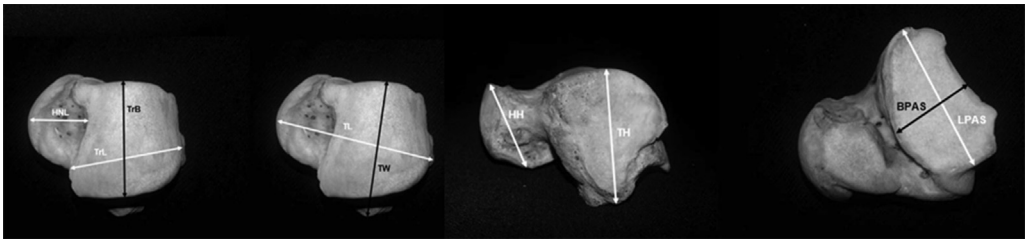

Fig. 1. Talus measurements: talar length (TL), head-neck length (HNL), trochlear length (TrL), length of posterior articular surface (LPAS), talar width (TW), trochlear breadth (TrB), breadth of posterior articular facet (BPAS), head height (HH), talar height (TH).